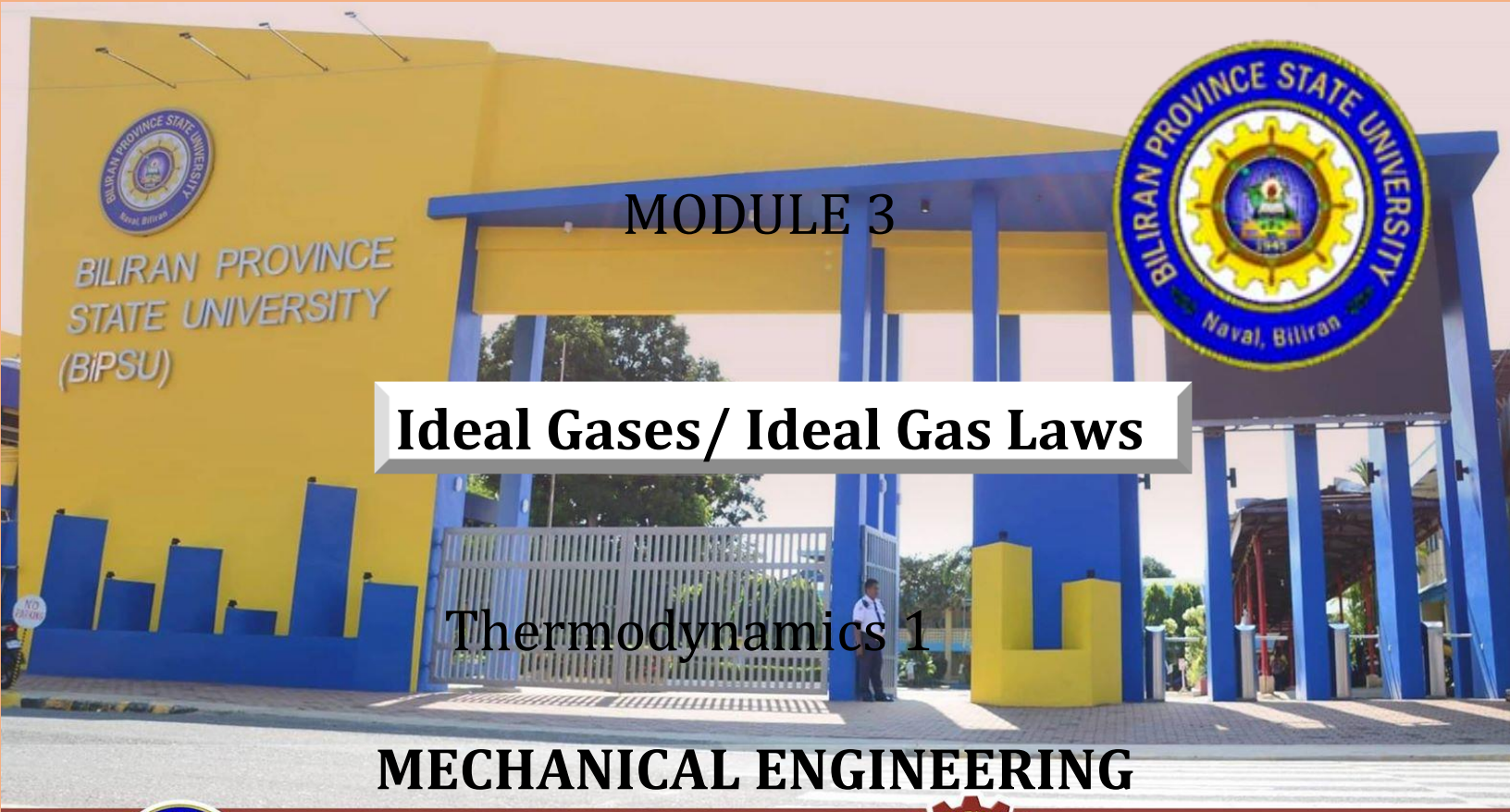

MODULE 3

Ideal Gases/ Ideal Gas Laws

Thermodynamics 1

MECHANICAL ENGINEERING

BILIRAN PROVINCE STATE UNIVERSITY — SCHOOL OF ENGINEERING

First Semester, SY 2020-2021

Course Code	:	ME 213
Course Title	:	Thermodynamics 1
Pre-requisite	:	Phys 123 & Phys 121L & Math 123 & Chem 113 and Chem 113L
Co-Requisite	:	None
Credit Units	:	3 units
Time Allotment	:	3 hours/week, 54 hours/semester
For this module	:	2 week only
Course Description	:	A course dealing with the thermodynamic properties of pure substances, ideal and real gases and the study and application of the laws of thermodynamics in the analysis of processes and cycles. It includes introduction to vapor and gas cycles.

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ACKNOWLEDGEMENT

To my ruler and controller in my life, thank you so much God for always guiding me to the right path of my daily life.

To my family, thank you for the moral support. I always acknowledge all of your efforts to make me comfortable in all my decisions.

RLPJR

PLEASE TELL YOUR SUGGESTIONS/COMMENTS

Communications are welcome from students, readers and professors especially for your concerning errors and comments for the improvement of this material. I spent more time in making this module yet, I believed that you will be part for the future enhancement of this module. Your comments will be highly appreciated. Please email to pitaoramonjr@gmail.com or rpitao@bipsu.edu.ph. Thank you…….

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Learning Module Purpose

- The purpose of this learning module is to introduce the principles of ideal gases and ideal gas laws and equations by presenting brief discussions and sample problems solution.
- To assess the learning outcomes of the students using this learning module.

Learning outcomes

- The students could be able to solved problems related to the ideal gas Law equations and they can apply the principles of ideal gas in solving thermodynamics related problems.

Learning guide

- Read and understand every topic of this module. It is important to understand the principles behind of each topic of this module since it is be useful for the next topic for this course.
- Perform and review each sample problem of this module. To further understand the content, go to the suggested reading for the links of references and videos for specific topic.
- This module is good for one week time only so manage your time properly.
- Perform the pre-assessment test below and follow the instruction accordingly.
- At the end part of the module, perform the post-assessment with proper solution and knowledgeable way as your learning outcomes. Take note that your rating of this post-assessment test is recorded.
- As the summary of your learning you will be task one presentation using Microsoft PowerPoint containing all the topic discuss in this module. You can go to the task summary or culminating activity at the last part of this module for the complete details.

Pre-assessment test

Solve the following problems with proper, systematic and clear solutions. Put always a box that indicate of your final answer(s).

1. A volume of 450 cc of air is measured at a pressure of 740 mm Hg absolute and a temperature of 20°C. What is the volume in cc at 760 mm Hg absolute and 0°C?

   Solution:

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2. The mas of air in the room 3m x 5m x 20m is known to be 350kg. Find its density.

   Solution:

3. The mas of air in the room 3m x 5m x 20m is known to be 350kg. If the pressure is 1atm What is the temperature of air?

   Solution:

4. A bicycle has a volume of 600 cm^3. It is inflated with carbon dioxide to pressure of 80 psi at 20°C. How many grams of carbon dioxide are contained in the tire?

   Solution:

5. An ideal gas at 0.60 atm and 87°C occupies 0.45 liter. How many moles are in the sample? Note! (R=0.0821 Li-atm/mole K)

   Solution:

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Principles and Brief discussions

General gas law is the equation of states of an ideal gas. It is a good approximation of the behavior of gases in relation to its pressure, volume and temperature.

Figure 1

In figure 1 the heat produces by the fuel will affect and can change the temperature of the surrounding air assuming that in the normal atmospheric condition.

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Figure 2

In figure 2, as the temperature of the air inside the balloon increasing by the flame, the density will decrease causing that the balloon goes up assuming that in the normal atmospheric condition.

Perfect Gas
Is a theoretically ideal gas which strictly follows Boyle's law and Charles' law of gases.

The equation of State of an Ideal Gas:

$$PV = mRT \text{ (in terms of mass)}$$
$$PV = nRT \text{ (in terms of moles)}$$
$$\bar{R} = MR$$

Where:
P= absolute pressure of the gas
M= molecular mass
V= volume of the gas
T= absolute temperature
m= mass of the gas
$\bar{R}$ = universal gas constant
R= ideal gas constant

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The Ideal Gas Constant or the Specific Gas Constant, R the ideal gas constant or the specific gas constant of a gas or a mixture of gasses is given by the Universal Gas Constant over the Molar Mass,

$$PV/T = mR$$
$$PV/T = n\bar{R}$$

Equating:

$$mR = \eta\bar{R}$$
$$R = \bar{R}m/n$$
$$R = \bar{R}/M$$

where:

$\bar{R}$ = universal gas constant
= 8.314 kJ/kg_{mol}-K (SI units)
=1545 ft-Ib/Ib_{mol}-°R (Eng'g units)
=1.9859Btu/ Ib_{mol}-°R

M =Molecular Mass, kg/kg_{mol}, kg/mol,Ib_m/Ib_{mol}

Relation between C_p, C_v, k & R:

$$C_p - Cv = R \qquad k = C_p / C_v$$

$$C_v = R/(k-1) \qquad C_p = kR/(k-1)$$

Where:
K = specific heat ratio (k = 1.4 for cold air)
C_v = specific heat at constant volume
C_p = specific heat at constant pressure (C_p=1.0 kJ/kg.K)

Charle's Law
A law stating that the volume of an ideal gas at constant pressure is directly proportional to the absolute temperature.

$$V \alpha T$$

Constant Pressure, $P_1 = P_2$ $V_1/T_2 = V_2/T_2$

Gay-Lussac's Law
States that the pressure of a given mass of a gas varies directly with the absolute temperature of the gas, when the volume is kept constant. The pressure of an ideal gas. If held at a constant volume is directly proportional to its temperature at any change of state.

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$$P \alpha T$$

Constant Volume, $V_1 = V_2$ $\quad P_1 / T_1 = P_2 / T_2$

Boyle's Law

A law stating that the pressure of a given mass of an ideal gas is inversely proportional to its volume at a constant temperature. If the temperature remained constant within a closed system, the volume of the gas varies inversely with the pressure during the change of state.

$$V \alpha 1/P$$

Constant Temperature, $\quad T_1 = T_2 \quad P_1 V_1 = P_2 V_2$

Examples:

1. A tank contains 20 kg of air at 200 kPa (gage) and 23°C. During the heating process the temperature of air rises. For safety purposes a technician installed a relief-type valve so that pressure of air inside the tank never exceeds 260 kPa (gage). At what air temperature the relief valve will start releasing air?

   Solution:

$$T_1 = 23 + 273 = 296K$$
$$P_1 = 200 + 101.325 = 301.325kPaa$$
$$P_2 = 260 + 101.325 = 361.325kPaa$$
$$T_2 = (T_1)\frac{P_2}{P_1} = (296)\frac{361.325}{301.325}$$

T_2 = 355 K, Ans.

2. Find the mass of carbon dioxide having a pressure of 20 psia at 200°F with 10 ft^3 volume.

   Solution:

   PV = mRT

$$(20x144)(10) = m(\frac{1545}{44})(200 + 460)$$

m = 1.24 lbs, Ans.

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3. A certain gas at 101.325 kPa and 10°C whose volume is 2.83 m^3 capacity. Before admission, the storage vessel contained gas at a pressure and temperature of 137.8 kPa and 26°C; after admission, the pressure increased to 1171.8 kPa. What should be the final temperature of the gas in the vessel in Kelvin?

Solution:

Mass of the gas to be compressed:

$PV = mRT$

$$m_1 = \frac{101.325(2.83)}{R(10+273)} = \frac{1.01325}{R}$$

Mass of the gas initially in the vessel:

$PV = mRT$

$$m_2 = \frac{137.8(0.31)}{R(26+273)} = \frac{0.14286}{R}$$

For final temperature, T_3:

$$m_3 = m_2 + m_1 = \frac{0.14286}{R} + \frac{1.01325}{R} = \frac{1.156}{R}$$

$P_3V_3 = m_3RT_3$

$$T_3 = \frac{117.8(0.31)}{(R)\frac{1.156}{R}}$$

T_3 = 314.2K, Ans.

Suggested videos

Ideal gas problem solving

1. https://youtu.be/TqLlfHBFY08
2. https://youtu.be/2ZtLDXF1V6w
3. https://youtu.be/0VaupcMr3oQ

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Post-assessment activity

Solve the following problems with proper and systematic solutions. Make the schematic diagram as an output of your analysis if the item required the diagram. Put always a box for each final answer.

1. An unknown gas has a mass of 1.5 kg and occupies 2.5 cubic meter while at a temperature of 300 degrees kelvin and a pressure of 200 kPa. Determine the ideal-gas constant for gas. (5pts)

   Solutions:

2. A motorist equips her automobile tires with a relief-type valve so that the pressure inside the tire never will exceed 240 kpa(gage). She starts a trip with a pressure 200 kpa(gage) and a temperature of 23 degrees C in the tires. During the long drive the temperature of the air in the tires reaches 83 degrees C. Each tire contains 0.11 kg of air. Determine (a) the mass of air escaping each tire;(b) the pressure of the tire when the temperature returns to 23 degrees C? (10pts)

   Solutions:

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3. A 6 cubic meter tank contains helium at 400 degrees K and is evacuated from atmospheric pressure to a pressure of 740 mm Hg vacuum. Determine (a) the mass of helium remaining in the tank; (b) the mass of helium pumped out. (c) The temperature of the remaining helium falls to 10 degrees C. What is the pressure in kpa? (15pts)

   Solutions:

4. A 1.5 kg quantity of ethane is cooled at a constant pressure from 170 degrees C. Determine (a) the change of enthalpy ;(b) the change of internal energy; (C) the heat transferred; (d) the work done.

   Solutions:

5. A 5 cubic meter tank contains chlorine at 300 kpa and 300 degrees K after 3 kg of chlorine has been used. Determine the original mass and a pressure if the original temperature was 315 degrees K.

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Solutions:

6. Determine the change of enthalpy for air and for carbon dioxide when the temperature changes from 70°F to 1000°F.

Solutions:

7. An ideal gas with molecular weight of $% expands at constant pressure from 150 degrees F to 350 degrees F. During the process 5.0 Btu are added to the gas, whose mass is 0.2 lbm. Determined the specific heat.

Solutions:

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8. An ideal gas at 0.60 atm and 87°C occupies 0.45 liter. How many moles are in the sample? Note! (R=0.0821 Li-atm/mole K).

Solutions:

9. A volume of 450 cc of air is measured at a pressure of 740 mm Hg absolute and a temperature of 20°C. What is the volume in cc at 760 mm Hg absolute and 0°C?

Solutions:

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10. The mas of air in the room 3m x 5m x 20m is known to be 350kg. If the pressure is 1atm what is the temperature of air?

Solutions:

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Culminating Activity

1. Prepared a presentable slides containing sample discussions and solving problems about
   a. Perfect Gas law equations (6 problems)
   b. Charles Law (3 problems) and Pressure five samples problems with solutions
   c. Boyles Law (3 problems)
   d. Gay-Lussac's Law (3 problems)

   Record your discussion using clear camera and audio and limit your discussion up to 5 minutes only per problem. Burn the output file including power point and video presentation into the compact disc CD or Digital Optical Disc DVD and submit this output to the School of Engineering Mechanical Department.

References

1. Thermodynamics an Engineering Approach 8th Edition by Yanus A. Cengel and Michael A. Boles.
2. Applied Physics 10th edition by Dale Ewen et. Al
3. Thermodynamics 1 by Hipolito B. Sta. Maria
4. Physics for Scientists and Engineers 8th edition volume 1 by Gordon et. Al.

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Core Values

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